EXPERIMENTAL SYSTEMS

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Introduction

The role of the ESG (Figure 1) can be split into several categories: (1) to design and build beamlines and endstations based on the demands of the user program, (2) to conduct forefront research in science and instrumentation that will push the boundaries of the application of synchrotron radiation techniques, and (3) to give support to existing user programs, usually in areas of high technical complexity. Approximately 50% of the group's activity is in this latter area of direct user support. This short report gives several examples of work in the two former areas and summarizes the group's activity over the broader range of its work.

Optical Metrology Laboratory

The main assignment of the Optical Metrology Laboratory (OML) at the ALS is the characterization, understanding, and adjustment of synchrotron radiation optics. This work, led by V. Yashchuk, is of growing importance as the ALS increases in brightness because of machine improvements and the use of new small-gap undulators. At the same time, our experiments are becoming more sophisticated, with emphasis on achieving small foci and reducing scattering. The OML carries out its mission using a number of metrology instruments, including a Micromap-570 interferometric microscope, a ZYGO GPI interferometer, a second-generation long-trace profiler, and a Polytec laser Doppler vibrometer. At the same time, the OML is working to investigate and improve the performance of these instruments and measurement techniques. As an example, one of the results of this work is reported here.

The Micromap-570 is a basic metrology tool for highly accurate testing of the surface finish of x-ray optics with sub-angstrom rms roughness. The standard list of output parameters of a Micromap measurement includes values of roughness averaged over

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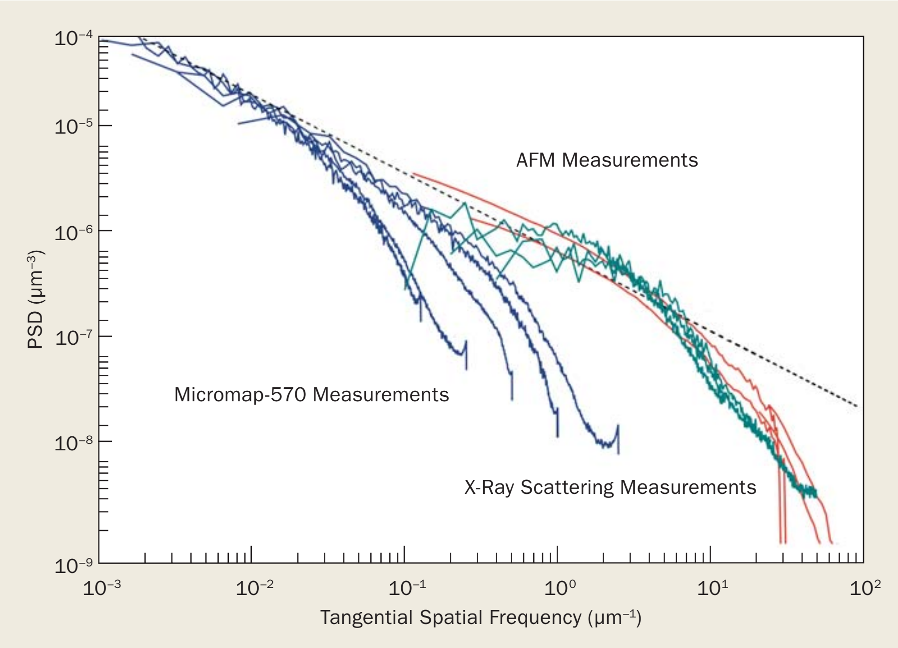
an area and along a sample line. However, the task of designing high-performance, low-scatter x-ray optical systems requires the development of sophisticated x-ray scattering calculations based on rigorous information about the optics.

One of the most insightful approaches to these calculations is based on the 2D power spectral density (PSD) distribution of the surface height, allowing for the evaluation of three-dimensional distributions of x rays scattered by the optics. A straightforward attempt to transform the area distribution of the residual surface heights available from the Micromap data file into a 2D PSD distribution fails because of the spectral distortion in the PSD caused by an unknown spatial



2 1D PSD spectra obtained using different techniques. Blue: Micromap-570 interferometric microscope (the different lines refer to different objectives used: 2×, 5×, 10×, 20×, and 50×). Cyan: Atomic force microscope (the different lines refer to different areas being measured: 5×5 µm^2, 10×10 µm^2, 20×20 µm^2, and 50×50 µm^2). Red: X-ray scattering measurements at two grazing angles, 1.5° and 5°. The dashed line represents a power-low spectrum, enveloping all the measured spectra.

frequency response function of the instrument. The distortion appears as a significant difference between the tangential and sagittal PSD spectra deduced from the 2D PSD distribution of an isotropic surface.

A detailed investigation of the origin of the anisotropy was performed at the OML, and a special procedure and relevant software were developed. An accurate 2D PSD can now be determined. The Micromap PSD measurement has been compared with measurements obtained using AFM and XRS. The measurements were performed on gold-coated stainless-steel substrate mirrors. The surface finish of the mirrors (fabricated by InSync) was found to be essentially isotropic, allowing straightforward comparison of the 1D PSD spectra obtained by convolution of the 2D PSD distributions measured with the Micromap, the AFM, and the 1D PSD spectra extracted from the XRS experiment (Figure 2).

The main conclusion from the cross-check is that all three techniques provide essentially consistent results. At spatial frequencies from ~0.1 to 50 µm^{-1}, the XRS measurements agree reasonably well with the AFM measurements. The frequency range available for the Micromap measurement is shifted to the lower frequencies, 0.001 to 2 µm^{-1}; nevertheless, in the overlapping range, good agreement between the PSD magnitudes can be seen. Moreover, the measurements are complementary, allowing for correction of the specific spatial-frequency-dependent systematic errors of the instruments.

The need for the evolution of mirror specifications to include the PSD characterization, and not just the rms roughness, requires development of a universal method to test and to calibrate the PSD measurement instruments available at different optical metrology laboratories at vendors and at user facilities around the world. Such a test method based on a specially designed pseudo-random grating is under development at the OML.

High-Pressure X-Ray Diffraction on Beamline 12.2.2

A new facility for x-ray diffraction and x-ray absorption spectroscopy from samples held at high pressures and temperatures has been built on Beamline 12.2.2, by a team led by S. Clark. This facility constitutes a central component of a center for high-pressure science being established at the ALS in support of the West Coast extreme-conditions community. It is designed to operate using diamond-anvil high-pressure cells with either resistive or laser heating, allowing combined temperatures and pressures in excess of 3000 K and 1 Mbar. The beamline benefits from the hard x rays generated by an ALS superbend. Useful x-ray flux is available between 5 and 35 keV.

The radiation is transferred from the superbend to the experimental enclosure by brightness-preserving optics. These optics consist of a vertically deflecting plane parabolic collimating mirror that provides parallel radiation in the vertical for a double-crystal monochromator (two flat crystals or two flat multilayers) followed by a toroidal focusing mirror. The various distances of the beamline components from the source are 6.5, 16.5, 18.8, and 28.2 m for the plane parabola, monochromator, toroid, and sample, respectively. This optical arrangement with the toroid in the 2:1 horizontal demagnification geometry results in the elimination of low-order aberrations and achieves a focus spot of high fidelity.

To cover the expected range of experimental requirements, two endstations are installed on a 3.6 × 1.2 m optical table, which in turn is placed within a spacious (5.4 × 3.2 m) hutch. After entering the hutch, the beam passes through a set of absorption foils, a fast shutter, a set of horizontal and vertical aperture slits, and a clean-up pinhole.

Endstation 1 has just been commissioned and is shown in Figure 3. It is optimized for the measurement of accurate unit-cell parameters to determine thermal equations of state of solid and liquid materials.